

Efficacy of Biofungicide Products for Foliar Diseases in Organically-Produced Tomato

Preliminary Report on an Experiment Funded by the IR-4 Biopesticide Program, 2008

This experiment consisted of a combination of two projects with products at the demonstration stage of development and at the advanced stage of development.

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Introduction

Foliar diseases of tomatoes are an important problem of an important crop. Fresh local tomatoes are one of the most popular items during summer, therefore they are grown by many organic and conventional growers. There are several foliar disease affecting tomatoes, including Septoria leaf spot, early blight, bacterial speck and spot, late blight, powdery mildew and leaf mold. Foliar diseases are a common occurrence wherever tomatoes are grown. All plantings are affected, even those grown under protection (greenhouses and high tunnels) and in small home gardens. Organic growers on Long Island have identified tomato as a high priority for research.

Foliar diseases need to be controlled in tomatoes to maintain yield. Yield is reduced when foliar diseases are not adequately controlled because the pathogen also infects fruit and/or death of infected leaves reduces fruit production and fruit quality, especially flavor. Diseases are often the reason tomato crops are abandoned before the last fruit are harvested. A long harvest period is needed with fresh market tomatoes for retail marketers because of consumer demand. This is especially true for organic growers who have CSAs.

Applications of fungicides are the main way foliar diseases are managed in both conventionally and organically-produced crops. Resistant varieties, unfortunately, are not available for foliar diseases that have been affecting production. Fungicides are likely to remain the main management tool because of the diversity of tomato varieties, and the popularity of heirloom varieties.

Organic growers are especially eager for efficacy data on biopesticides because they would like to obtain better control of foliar diseases and prefer not to rely on copper. Conventional growers have been increasingly interested in biopesticides and other biocompatible products. Growers are reluctant to try new products without data from replicated evaluation studies documenting efficacy because of the potential impact of using an ineffective product.

This project is addressing an important priority for vegetable growers, which is not specifically an IR-4 priority. However, the project will provide some information toward two priorities. Powdery mildew and leaf mold are also important diseases for tomatoes grown in greenhouses and high tunnels in the northeast.

Materials and Methods

The following biopesticides were selected for evaluation:

1. Actinovate SP. 0.0371% *Streptomyces lydicus*. Labeled for suppressing several foliar and soil-borne diseases on many crops; diseases and crops listed separately. The biocontrol agent colonizes roots, protecting them from pathogens and making minerals and micronutrients more available to plants, which thus are more vigorous and larger. Pathogens and diseases listed include *Alternaria*, *Anthracnose*, *Botrytis*, *Fusarium*, *Phytophthora*, *Pythium*, *Sclerotinia*, *Verticillium*, and powdery mildew. OMRI listed. EPA Reg. No. 73314-1. Natural Industries, Inc.
2. Companion. 0.03% *Bacillus subtilis* GB03. Activates induced systemic resistance in plants. Labeled for several soil and foliar diseases on many crops, including bacterial leaf spot, buckeye rot, early blight, Fusarium wilt, gray mold, late blight, Pythium root rot, Rhizoctonia stem rot, and Sclerotinia white mold in the fruiting vegetables crop group, which includes tomato. EPA Reg. pending. OMRI listed. Growth Products, Ltd.
3. MOI-106 (aka Regalia SC). 5% Extract of *Reynoutria sachalinensis*. Boosts the plants' natural defense mechanisms against certain fungal and bacterial diseases. Labeled for use against bacterial blight, bacterial canker, bacterial leaf spot, bacterial speck, gray mold, early blight, late blight, powdery mildew and target spot on tomato and for several diseases on several other crops. Rate: 0.5-1%. OMRI listed. EPA Reg. No. 84059-2. Marrone Organic Innovations, Inc. \$13-15/A.
4. Organocide. 5% sesame oil. Labeled broadly for several fungal diseases and insects. Exempt from EPA registration. Organic Laboratories, Inc.
5. Sporatec AG. 18% rosemary oil, 10% clove oil, and 10% thyme oil. Labeled for several bacterial and fungal diseases on many crops, including, but not limited to, bacterial spot, early blight, gray mold, late blight, and powdery mildew in the legume and fruiting vegetables crop groups, which includes tomato. OMRI listed. Exempt from EPA registration. Clawel, division of Brandt Consolidated.
6. Taegro. *Bacillus subtilis* var. *amyloliquefaciens* strain FZB24 24.5%. Labeled presently for suppressing several fungal root disease pathogens such as *Rhizoctonia* and *Fusarium*. Not OMRI listed. EPA Reg. No. 70127-5. Novozymes Biologicals, Inc.

An experiment was conducted in a field of Haven loam soil at LIHREC (Cornell's research facility in Riverhead NY) that has been assigned to research on organic vegetable production. There were four replications. Plots consisted of single rows of 10 plants spaced 2 ft apart.

Tomato variety NC 8276 PVP from Outstanding Seeds was used. It was seeded into Sunshine Organic mix on 12 May. Seedlings grew slowly and poorly indicating inadequate fertilizer in the mix. Therefore Biolink 5-5-5 Organic fertilizer (60 ml per 1 gal water) was applied on 5 and 26 June. Seedlings were no-till transplanted on 1 July into straw mulch from spring-planted triticale. The field was fertilized with Pro-Grow organic fertilizer at 1000 lb/A (= 50 lb N/A) before seeding the triticale at 125 lb/A in April. Fish emulsion (Neptune's Harvest) was put in the transplant hole before setting the seedlings. Pro-Grow organic fertilizer at 1000 lb/A was banded across the row at planting. Drip tape was laid next to each row. Additional straw mulch was spread around plants. Plants were staked and trellised following standard procedure for fresh-market tomato production. The insecticide Ensure was applied regularly to control worm pests.

Treatment applications were made using a CO₂-pressurized backpack sprayer with a boom that has a single twin-jet 180-degree nozzle. Each side of the planted row was treated with the boom held sideways to obtain thorough coverage of foliage. Applications were made weekly beginning on 21 July for the conventional fungicide program and on 20-21 Aug for most of the other treatments, which was before diseases were expected to begin developing based on crop physiology. The treatments with Sporatec were started on 28 Aug. The conventional program was started earlier following the guidelines for Actigard for bacterial speck management. Application dates were 21 and 30 July; 7, 14, 20-21, and 28 Aug; and 4, 10, 17, 24, and 30 Sep. For two treatments the Kocide rate was increased over time from lowest to highest label rate (0.75 to 1.75 lb/A). BioLink, an organic adjuvant, was applied with Actinovate and with Sporatec. Sporatec was also tested tank-mixed with Saf-T-Side, an OMRI-listed spray oil emulsion with 80% petroleum oil that is labeled for use as a fungicide, insecticide, and miticide. Low rates (0.75 and 1 lb/A) were used in the conventional fungicide program. The program used was not a true standard because Actigard was inadvertently continued in the alternation program through the marketable fruit production period, for which this product is not labeled.

Disease incidence and severity were assessed on 15, 22, and 29 Sep and 6 Oct. Incidence was assessed as the proportion of leaflets with symptoms. Severity was assessed for symptomatic leaflets only. Severity for the entire canopy was calculated by multiplying the average symptomatic leaflet severity value by incidence. A square root transformation was used for all variables when needed prior to analysis to achieve homogeneity of variance.

Tomato fruit were not harvested due to the anticipated confounding effect on yield of variable damage among plots that occurred during the unusual severe storms.

Preliminary Results

Conditions were not ideal for tomato production in 2008 with several severe rainstorms that included hail and strong winds as well as heavy rain.

Diseases developed naturally in the research field. Symptoms were not seen until around the time that the first ripe fruit were seen, which was 9 Sep. The third or fourth application was made for each of the biopesticide treatments on 10 Sep. Dates of first observations were 10 Sep for powdery mildew, 15 Sep for Septoria leaf spot and 3 Oct for late blight. Powdery mildew and Septoria leaf spot have been the primary diseases in past experiments at this location. Bacterial speck and leaf mold have also occurred.

All treatments provided some suppression of powdery mildew based on the incidence assessment on 6 Oct (Table 1). Seven treatments were highly effective providing at least 90% control, which was not significantly different from either the organic treatment standard or the conventional fungicide program. For the other four assessments included in the table, values for some treatments were not significantly different from the nontreated control. However, others provided a high level of control based on all assessments. Control was always at least 87% for MOI-106 (applied alone or alternated with Kocide), Sporatec + Saf-T-Side and **Organocide + Kocide 3000**.

Septoria leaf spot was suppressed by all treatments except Taegro and Sporatec (Table 2). Degree of control was not as high as that obtained for powdery mildew, even with the standard organic fungicide and with the conventional fungicide program

All plots receiving treatments that effectively controlled Septoria leaf spot exhibited significantly less defoliation on 6 Oct than the nontreated control. Percent defoliation was 27% for the nontreated control, 1% for the organic and conventional fungicide programs, and ranged from 9 to 27 % for the biopesticide treatments not effective for Septoria and from 1 to 7% for the effective biopesticide treatments. Loss of leaves in tomato results in fruit exposed and vulnerable to sunscald and other damage. Yield may be reduced. And, most importantly, loss of leaves often is associated with a decline in quality of fruit, particular the flavor.

The standard conventional fungicide program was not significantly better than the standard organic fungicide program. Several biopesticides tested controlled Septoria leaf spot and powdery mildew as effectively as both standard programs (Tables 1 and 2).

Actinovate SP was moderately effective for powdery mildew and for Septoria leaf spot. Control of powdery mildew was 68% based on incidence on 29 Sep and 49% for Septoria based on incidence on 6 Oct. However, severity and incidence values on some assessment dates were not significantly different from the nontreated control.

Companion provided control of both powdery mildew and Septoria leaf spot. There was one assessment value for each disease that was not significantly lower than the nontreated control. Control achieved with the high rate (1 gal/A) was not significantly

better than that with the low rate (0.5 gal/A). Similar to the other biopesticides, Companion was more effective for powdery mildew. Control obtained with the low rate was 14 to 72% for Septoria and 68 to 95% for powdery mildew.

MOI-106 provided excellent suppression of powdery mildew (91 to 99% for the five assessments in Table 1). Septoria leaf spot was also suppressed based on most assessments. Based on the 6 Oct assessments, level of control was significantly better when MOI-106 was applied in alternation with Kocide 3000 rather than used every week: 59% versus 20% control for severity and 84% versus 50% for incidence.

Organocide provided good control of Septoria leaf spot based on incidence data (47 to 62%) and excellent control of powdery mildew (79 to 97%). Control was improved, sometimes significantly, when Organocide was applied at half the rate tank-mixed with Kocide 3000 at the lowest label rate.

Sporatec AG applied with BioLink controlled powdery mildew but not Septoria leaf spot. Degree of control of powdery mildew ranged from 61 to 88%. However, excellent control of both diseases was obtained when Sporatec was mixed with Saf-T-Side: 65 to 91% for Septoria and 91 to 100% for powdery mildew. Degree of control was never significantly different from the organic standard and was significantly lower than the conventional fungicide program for only 1 of the 10 assessments in the tables.

Taegro exhibited some suppression of powdery mildew based on the 6 Oct incidence data. It was ineffective for Septoria leaf spot. This is the only product tested that is not labeled yet for any foliar diseases. It is marketed now for root diseases. Applying Taegro initially as a soil drench before diseases have started to develop may be a more appropriate method to achieve control of foliar diseases.

Table 1. Efficacy of six biopesticides for powdery mildew in organically-produced tomato compared with a copper fungicide (organic standard) and a conventional fungicide program.

Treatment and rate (application date) ^y	Powdery mildew severity (%) ^z		Powdery mildew incidence (%) ^z		
	29-Sep	6-Oct	22-Sep	29-Sep	6-Oct
Nontreated	19.0 a ^x	21.6 a	7.4 a	14.0 a	71.9 a
Taegro 3.5 oz/100 gal (5-11)	18.6 a	14.2 ab	5.3 ab	10.9 a	50.6 b
Taegro 3.5 oz/100 gal (1,3,5,7,9,11) alt MOI-106 1% (2,4,6,8,10)	3.2 bcd	11.0 bc	0.4 cd	0.9 cd	16.1 cde
Actinovate 12 oz/A + BioLink 2 fl oz/gal (5-11)	8.7 ab	14.8 ab	2.4 bc	4.5 b	27.9 c
MOI-106 1% (5-11)	0.5 cde	2.9 efg	0.3 cd	0.2 def	2.8 e
MOI-106 1% (1,3,5,7,9,11) alt Kocide 3000 0.75-1.75 lb/A (2,4,6,8,10)	1.1 cde	1.9 fgh	0.2 d	0.2 def	0.5 e
Companion 0.5 gal/A (5-11)	1.0 cde	6.8 cde	0.8 cd	0.7 de	7.5 de
Companion 1 gal/A (5-11)	8.8 ab	7.9 bcd	0.8 cd	0.8 de	3.4 e
Sporatec AG 2 pt/A + BioLink 2 fl oz/gal (6-11)	5.4 bc	8.5 bcd	0.9 cd	2.9 bc	25.9 cd
Sporatec AG 2 pt/A + Saf-T-Side 1.5% (6-11)	0.0 de	1.9 fgh	0.0 d	0.0 ef	0.8 e
Organocide 2 oz/gal (5-11)	0.9 cde	4.5 def	0.6 cd	0.5 def	2.3 e
Organocide 1 oz/gal + Kocide 3000 0.75 lb/A (5-11)	0.1 de	2.3 efg	0.1 d	0.1 def	0.8 e
Standard organic fungicide: Kocide 3000 0.75-1.75 lb/A (5-11)	0.1 de	0.6 gh	0.1 d	0.1 def	0.3 e
Conventional fungicide program: Actigard 0.3-0.75 oz/A (1,3,5,7,9,11); Kocide 3000 0.75-1 lb/A + Dithane 1.5 lb/A (2,4,6,8,10); Flint 2.5 oz/A (4,8)	0.0 e	0.2 h	0.0 d	0.0 f	0.2 e
<i>P</i> -value (treatment)	< .0001	< .0001	0.0001	< .0001	< .0001

^z Severity is proportion of leaf tissue with symptoms for affected leaves. Incidence is percentage of leaflets with symptoms.

^y Applications were made weekly beginning on 21 July for the conventional fungicide program and 20-21 or 28 Aug for the other treatments. Application dates were 1=21 July, 2=30 July, 3=7 Aug, 3=14 Aug, 5=20-21 Aug, 6= 28 Aug, 7= 4 Sep, 8=10 Sep, 9=17 Sep, 10=24 Sep, and 11=30 Sep. For three treatments the Kocide rate was increased over time.

^x Numbers in each column followed by the same letter are not significantly different from each other according to Fisher's protected LSD ($P=0.05$).

Table 2. Efficacy of six biopesticides for Septoria leaf spot in organically-produced tomato compared with a copper fungicide (organic standard) and a conventional fungicide program.

Treatment and rate (application date) ^y	Septoria leaf spot severity (%) ^z		Septoria leaf spot incidence (%) ^z		
	29-Sep	6-Oct	22-Sep	29-Sep	6-Oct
Nontreated	43.1 a ^x	30.4 ab	3.2	22.1 ab	87.5 a
Taegro 3.5 oz/100 gal (5-11)	42.5 ab	40.0 a	4.0	25.2 a	76.6 ab
Taegro 3.5 oz/100 gal (1,3,5,7,9,11) alt MOI-106 1% (2,4,6,8,10)	20.1 cd	30.6 ab	3.3	20.4 ab	53.3 bc
Actinovate 12 oz/A + BioLink 2 fl oz/gal (5-11)	36.9 abc	26.3 bc	1.2	10.2 abcd	44.6 c
MOI-106 1% (5-11)	30.1 abc	24.4 bcd	0.6	5.4 cde	43.4 c
MOI-106 1% (1,3,5,7,9,11) alt Kocide 3000 0.75-1.75 lb/A (2,4,6,8,10)	19.4 cd	12.5 ef	0.7	2.9 de	13.7 d
Companion 0.5 gal/A (5-11)	23.3 bcd	26.3 bc	1.6	6.1 cde	45.0 c
Companion 1 gal/A (5-11)	27.5 abcd	17.5 cde	1.5	5.8 cde	50.0 bc
Sporatec AG 2 pt/A + BioLink 2 fl oz/gal (6-11)	26.4 abcd	30.0 ab	2.2	16.6 abc	63.5 abc
Sporatec AG 2 pt/A + Saf-T-Side 1.5% (6-11)	31.3 abc	10.6 ef	0.9	1.9 de	8.4 d
Organocide 2 oz/gal (5-11)	36.9 abc	27.5 bc	1.2	8.3 bcd	46.8 c
Organocide 1 oz/gal + Kocide 3000 0.75 lb/A (5-11)	21.3 cd	12.1 ef	1.3	3.6 de	13.3 d
Standard organic fungicide: Kocide 3000 0.75-1.75 lb/A (5-11)	23.8 abcd	15.1 def	0.7	2.9 de	12.5 d
Conventional fungicide program: Actigard 0.3-0.75 oz/A (1,3,5,7,9,11); Kocide 3000 0.75-1 lb/A + Dithane 1.5 lb/A (2,4,6,8,10); Flint 2.5 oz/A (4,8)	10.1 d	5.1 f	0.2	0.6 e	0.4 d
<i>P</i> -value (treatment)	0.0599	< .0001	0.1607	0.0004	< .0001

^z Severity is proportion of leaf tissue with symptoms for affected leaves. Incidence is percentage of leaflets with symptoms.

^y Applications were made weekly beginning on 21 July for the conventional fungicide program and 20-21 or 28 Aug for the other treatments. Application dates were 1=21 July, 2=30 July, 3=7 Aug, 3=14 Aug, 5=20-21 Aug, 6= 28 Aug, 7= 4 Sep, 8=10 Sep, 9=17 Sep, 10=24 Sep, and 11=30 Sep. For three treatments the Kocide rate was increased over time.

^x Numbers in each column except the first followed by the same letter are not significantly different from each other according to Fisher's protected LSD ($P=0.05$).